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NOTICE OF ALLOWANCE AND FEE(S) DUE

33787 7590 02/14/2006

JOHN J. OSKOREP, ESQ.
ONE MAGNIFICENT MILE CENTER
980 N. MICHIGAN AVE.
SUITE 1400
CHICAGO, IL 60611

| | |
|-------------------------|--------------|
| EXAMINER | |
| KIM, PAUL D | |
| ART UNIT | PAPER NUMBER |
| 3729 | |
| DATE MAILED: 02/14/2006 | |

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|-----------------|-------------|----------------------|---------------------|------------------|
| 10/825,507 | 04/15/2004 | Edward Hin Pong Lee | SJ09-2002-0018US2 | 8550 |

TITLE OF INVENTION: METHOD OF PROVIDING PROTECTION TO THE POLE PIECE OF A MAGNETIC HEAD DURING ITS MANUFACTURE WITH USE OF A SELECTIVELY ETCHEABLE MATERIAL

| APPLN. TYPE | SMALL ENTITY | ISSUE FEE | PUBLICATION FEE | TOTAL FEE(S) DUE | DATE DUE |
|----------------|--------------|-----------|-----------------|------------------|------------|
| nonprovisional | NO | \$1400 | \$300 | \$1700 | 05/15/2006 |

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE REFLECTS A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE APPLIED IN THIS APPLICATION. THE PTOL-85B (OR AN EQUIVALENT) MUST BE RETURNED WITHIN THIS PERIOD EVEN IF NO FEE IS DUE OR THE APPLICATION WILL BE REGARDED AS ABANDONED.

HOW TO REPLY TO THIS NOTICE:

I. Review the SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:

A. If the status is the same, pay the TOTAL FEE(S) DUE shown above.

B. If the status above is to be removed, check box 5b on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and twice the amount of the ISSUE FEE shown above, or

If the SMALL ENTITY is shown as NO:

A. Pay TOTAL FEE(S) DUE shown above, or

B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check box 5a on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and 1/2 the ISSUE FEE shown above.

II. PART B - FEE(S) TRANSMITTAL should be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). Even if the fee(s) have already been paid, Part B - Fee(s) Transmittal should be completed and returned. If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: **Mail Stop ISSUE FEE**
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INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

33787 7590 02/14/2006

JOHN J. OSKOREP, ESQ.
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Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)

(Signature)

(Date)

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|----------------|--------------|-----------|-----------------|------------------|------------|
| nonprovisional | NO | \$1400 | \$300 | \$1700 | 05/15/2006 |
| EXAMINER | | ART UNIT | | CLASS-SUBCLASS | |
| KIM, PAUL D | | 3729 | | 029-603120 | |

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
 "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. Use of a Customer Number is required.

2. For printing on the patent front page, list

(1) the names of up to 3 registered patent attorneys or agents OR, alternatively,
 (2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 _____
 2 _____
 3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent): Individual Corporation or other private group entity Government

4a. The following fee(s) are enclosed:

Issue Fee
 Publication Fee (No small entity discount permitted)
 Advance Order - # of Copies _____

4b. Payment of Fee(s):

A check in the amount of the fee(s) is enclosed.
 Payment by credit card. Form PTO-2038 is attached.
 The Director is hereby authorized to charge the required fee(s), or credit any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. Change in Entity Status (from status indicated above)

a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27. b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

The Director of the USPTO is requested to apply the Issue Fee and Publication Fee (if any) or to re-apply any previously paid issue fee to the application identified above. NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature _____

Date _____

Typed or printed name _____

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This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

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| 33787 | 7590 | 02/14/2006 | EXAMINER | |
| JOHN J. OSKOREP, ESQ. ONE MAGNIFICENT MILE CENTER 980 N. MICHIGAN AVE. SUITE 1400 CHICAGO, IL 60611 | | | | KIM, PAUL D |
| 3729 | | ART UNIT PAPER NUMBER | | |
| DATE MAILED: 02/14/2006 | | | | |

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b) (application filed on or after May 29, 2000)

The Patent Term Adjustment to date is 241 day(s). If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the Patent Term Adjustment will be 241 day(s).

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (<http://pair.uspto.gov>).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

| | | |
|-------------------------------|-------------------------|----------------------|
| Notice of Allowability | Application No. | Applicant(s) |
| | 10/825,507 | LEE, EDWARD HIN PONG |
| | Examiner Paul D. Kim | Art Unit 3729 |

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTO-85) or other appropriate communication will be mailed in due course. THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS. This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. This communication is responsive to 4/15/2004.
2. The allowed claim(s) is/are 19-35.
3. Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
 - a) All
 - b) Some*
 - c) None
 of the:
 1. Certified copies of the priority documents have been received.
 2. Certified copies of the priority documents have been received in Application No. _____.
 3. Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

* Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

4. A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.
5. CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
 - (a) including changes required by the Notice of Draftsperson's Patent Drawing Review (PTO-948) attached
 - 1) hereto or 2) to Paper No./Mail Date _____.
 - (b) including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).
6. DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

| | |
|---|--|
| 1. <input checked="" type="checkbox"/> Notice of References Cited (PTO-892) | 5. <input type="checkbox"/> Notice of Informal Patent Application (PTO-152) |
| 2. <input type="checkbox"/> Notice of Draftsperson's Patent Drawing Review (PTO-948) | 6. <input type="checkbox"/> Interview Summary (PTO-413), Paper No./Mail Date _____. |
| 3. <input checked="" type="checkbox"/> Information Disclosure Statements (PTO-1449 or PTO/SB/08), Paper No./Mail Date <u>4/15/04</u> | 7. <input checked="" type="checkbox"/> Examiner's Amendment/Comment |
| 4. <input type="checkbox"/> Examiner's Comment Regarding Requirement for Deposit of Biological Material | 8. <input checked="" type="checkbox"/> Examiner's Statement of Reasons for Allowance |
| | 9. <input type="checkbox"/> Other _____. |

EXAMINER'S AMENDMENT

1. An examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

Authorization for this examiner's amendment was given in a telephone interview with Mr. Oskorep on 2/7/2006.

The application has been amended as follows:

IN THE SPECIFICATION

Re. Abstract: Before the phrase "depositing yoke layer" in line 10, insert --and--.

After the phrase "the resulting structure" in line 11, replace ";" and performing a chemically...to thereby form a yoke" to --.--.

IN THE CLAIM

Re. Claim 19: Before the phrase "structure" as recited in line 14, replace the phrase "resulting" to --entire--.

Re. Claim 26: Before the phrase "structure" as recited in line 7, replace the phrase "the resulting structure" to --the front pole tip and the insulating materials--.

2. The following changes to the drawings have been approved by the examiner and agreed upon by applicant: Insert --Prior Art—to Figs. 3-9. In order to avoid

Art Unit: 3729

abandonment of the application, applicant must make these above agreed upon drawing changes.

3. The following is an examiner's statement of reasons for allowance: The prior art of record fails to disclose the claimed invention such as a process of etching to remove the selectively etchable material layer and depositing yoke layer material over the entire structure to form a yoke. The closest reference, Han et al. (US PAT. 6,504,677) teach a process of making write head including a front pole tip (44), a back gap pedestal (52), and insulator materials (54) disposed between the front pole tip and the back gap pedestal and forming a layer of selectively etchable materials (46) over the top surface of the partially constructed magnetic head, the layer having a front edge that is recessed away from an air bearing surface (ABS) and forming additional insulator materials (54) over the selectively etchable material layer and over a front portion of the front pole tip and forming a yoke layer material (48) on the selectively etchable material layer and forming an additional insulator materials (56) to fill a recess away from an air bearing surface as shown in Fig. 2. However, Han et al. fail to teach to remove the selectively etchable material prior to form the yoke layer. Therefore, it would not be obvious to modify Han et al. by removing the etchable material prior to form the yoke layer, since doing so would destroy the structure of write head of Han et al.

4. Claims 19-35 are allowed.

5. Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably

accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Paul D. Kim whose telephone number is 571-272-4565. The examiner can normally be reached on Monday-Friday between 6:00 AM to 2:00 PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Peter Vo can be reached on 571-272-4690. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).



Paul D Kim
Examiner
Art Unit 3729

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Substitute for form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet 1 of 2

| Complete if Known | |
|------------------------|------------------|
| Application Number | Not Yet Assigned |
| Filing Date | Not Yet Assigned |
| First Named Inventor | Lee |
| Art Unit | Not Yet Assigned |
| Examiner Name | Not Yet Assigned |
| Attorney Docket Number | SJG920020018US2 |

U. S. PATENT DOCUMENTS

FOREIGN PATENT DOCUMENTS

| Examiner Initials* | Cite No. ¹ | Foreign Patent Document | Publication Date MM-DD-YYYY | Name of Patentee or Applicant of Cited Document | Pages, Columns, Lines, Where Relevant Passages Or Relevant Figures Appear | T |
|--------------------|-----------------------|--|--------------------------------|--|---|---|
| | | Country Code ² Number ⁴ Kind Code ⁵ (# known) | | | | |
| pd | 03-275249 | | 10/23/1991 | Yoshiro et al. | | |
| par | JP406004830A | | 01/14/1991 | Saito | | |
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¹EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. ²Applicant's unique citation designation number (optional). ³See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. ⁴Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). ⁵For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁶Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. ⁷Applicant is to place a check mark here if English language Translation is attached.

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 (1-800-786-9199) and select option 2.

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**INFORMATION DISCLOSURE
STATEMENT BY APPLICANT**

(Use as many sheets as necessary)

Sheet

2

of

2

| Complete If Known | |
|------------------------|------------------|
| Application Number | Not Yet Assigned |
| Filing Date | Not Yet Assigned |
| First Named Inventor | Lee |
| Art Unit | Not Yet Assigned |
| Examiner Name | Not Yet Assigned |
| Attorney Docket Number | SJO920020018US2 |

NON PATENT LITERATURE DOCUMENTS

| Examiner Initials* | Cite No. ¹ | Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published. | T ² |
|--------------------|-----------------------|---|----------------|
| <i>jl</i> | | R.T. CAMPBELL, V. ESCALANTE, R. LEE AND J.LO, Perfectly Aligned Pole Tips By Using Full Film P2 Process With Al2O3 Protection Layer, Research Disclosure, April 1987, Number 276, Kenneth Mason Publications Ltd., England. | |
| <i>✓</i> | | YINGJIAN CHEN; LIU, F.; STOEV, K.; XIAOZHONG DANG; HUA-CHING TONG; QING HE; YIMING HUAI; "High-performance writer using high-moment sputtered fields in top and bottom poles"; IEEE Transactions on, Volume 38, Issue: 5, Sept. 2002. | |
| <i>✓</i> | | Preliminary amendment for divisional application having Docket No. SJO920020018US3 which is based on parent Serial No. 10/156,633. | |
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| Examiner Signature | <i>Paul</i> | Date Considered | 2/6/06 |
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*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

1 Applicant's unique citation designation number (optional). 2 Applicant is to place a check mark here if English language Translation is attached.

This collection of information is required by 37 CFR 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

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| | | |
|-----------------------------------|---------------------------------------|--|
| Notice of References Cited | Application/Control No. 10/825,507 | Applicant(s)/Patent Under Reexamination LEE, EDWARD HIN PONG |
| | Examiner Paul D. Kim | Art Unit 3729 |

U.S. PATENT DOCUMENTS

| * | | Document Number Country Code-Number-Kind Code | Date MM-YYYY | Name | Classification |
|---|---|--|-----------------|------------|----------------|
| * | A | US-6,504,677 | 01-2003 | Han et al. | 360/126 |
| | B | US- | | | |
| | C | US- | | | |
| | D | US- | | | |
| | E | US- | | | |
| | F | US- | | | |
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| | M | US- | | | |

FOREIGN PATENT DOCUMENTS

| * | | Document Number Country Code-Number-Kind Code | Date MM-YYYY | Country | Name | Classification |
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NON-PATENT DOCUMENTS

| | | |
|---|---|---|
| * | | Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages) |
| | U | "The effect of track width and topography on composition uniformity of electroplated Permalloy in thin film heads"; Sahami, S.; Lee, H.P.E.; Magnetics, IEEE Transactions on Volume 28, Issue 5, Part 2, Sep 1992; Pages:2103 - 2105. |
| | V | |
| | W | |
| | X | |

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

THE EFFECT OF TRACK WIDTH AND TOPOGRAPHY ON COMPOSITION UNIFORMITY OF ELECTROPLATED PERMALLOY IN THIN FILM HEADS

Saeed Sahami and H. P. Edward Lee

IBM Corporation, Storage Systems Products Division,
5600 Cottle Road, San Jose, CA 95193

Abstract—The composition difference of the plated Permalloy in thin-film heads from pole tip to yoke was studied as a function of the track width and topography. The variation of the track width ranged from 5 to 26 microns and of the topographical height from 0 to 20 microns. Results showed that there was no composition difference for flat structures. However, as the topographical height increased from zero to 20 microns, the composition difference between the yoke and pole tip changed from zero to 0.5%. In all cases, it was found that higher topographical area are Fe-rich. This difference was explained by the diffusion mechanism as opposed to a current crowding model. It was concluded that electroplating can be employed to deposit Permalloy in track widths as narrow as 5 microns without substantial degradation in composition uniformity.

I. INTRODUCTION

Thin-film recording heads are fabricated either by "dry" process or "wet" process. In the dry process, sputtering and ion etching are used for deposition and pattern definition, respectively [1,2]. In the case of wet processing, a combination of dry process, photolithography patterning and electrochemical deposition are employed [3,4]. For most manufacturers, Permalloy layers in the thin-film inductive heads are deposited by electroplating. The absolute composition of the Permalloy as well as its uniformity over the flat and stepped portion of the head play an important role in the read/write characteristics and magnetic performance of thin-film heads [2,5-9].

Increasing magnetic recording density requires reduction of the track width of magnetic heads. One of the motivations for this work was to study the limit of electroplating, i.e., how narrow one can plate Permalloy and still get uniform composition. The two major mechanisms which can explain the composition nonuniformity of the electroplated Permalloy are related to current density and mass transfer variations. The effect of current (density) on composition has been studied [7,10]. Several authors have postulated that the composition difference is due to the current density differences at yoke and pole tip during plating [2,7].

Manuscript received February 17, 1992

In this paper, composition variation of the electroplated Permalloy films as a function of pole width and step height is reported. Experiments were also performed to examine the effect of mass transfer and current density.

II. EXPERIMENTAL

The test structures (heads) were prepared using conventional wet process for thin-film head fabrication. For structures with taller topography, hard baked photoresist was used for the additional height. Electroplating of Permalloy films was carried out in a system described in [11], using a reciprocating paddle cell similar in principle to the one in [12]. The NiFe magnetic layer thickness was varied from 1 to 3.2 microns. All Permalloy films were prepared using a chloride-sulfate bath [13] with identical plating conditions (i.e., constant bath chemistry, temperature, agitation and theoretical current density). The NiFe composition of each head at wafer level was measured with a JEOL 733 electron probe micro analyzer with wavelength dispersive spectrum (EPMA/WDS). Fig. 1 shows a top view of a head, and pole tip and yoke locations where composition was measured. Each composition value reported in this paper, is an average composition of at least 30 heads measured on a wafer. The EPMA measurement was corrected for the effect of the



Fig. 1 Top view of a typical thin-film head and locations where composition was measured.

secondary X-ray fluorescence. The track width of pole tips was defined by photoresist frame patterning. In some experiments, a pole trimming technique by Ar gas ion milling was used to reduce pole width.

III. RESULTS AND DISCUSSION

Permalloy composition difference between the yoke and pole tip as a function of the plated pole width are shown in Fig. 2. All measured heads in this figure had different pole width and Permalloy thickness. The results showed that there is no composition dependency on Permalloy thickness in the range of 1 to 3.2 microns. Two groups of data are presented in Fig. 2. The topographical structure of group 1 had a height of 17 microns and that of group 2 was on a flat structure, i.e., pole tip and yoke were at the same level. It appears from Fig. 2 that the composition difference approaches a plateau at about 0.4% Fe for pole widths greater than 14 microns for structures with 17 microns step height. Although, the magnitude of the composition difference for flat structures is smaller than that of those with 17 microns topography, the trend of change is similar, i.e., the apparent composition difference decreased as the pole width increased.

To understand if the change in composition is caused by electroplating in the narrow geometry, the topography, or by the artifact of the electron microprobe measurement technique, the following experiments were performed: 1) A wafer with a pole tip track width of 26 microns and topography of 17 microns was electroplated. The track width of this wafer was then reduced to 8 microns by ion mill trimming of the pole tip only. As is shown in Fig. 3, the composition measurement before and after pole tip trimming revealed that the composition difference between yoke and pole tip has increased from 0.4 to 0.8% Fe as the track width

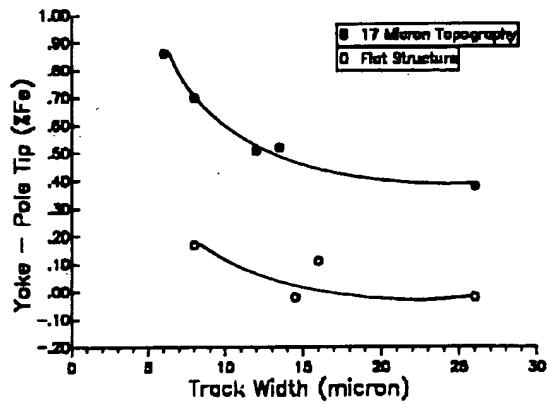


Fig. 2 Composition difference between the yoke and pole tip as a function of the plated track width.

decreased from 26 to 8 microns. 2) In the second experiment, a flat structure (zero topography) with pole tip track width of 14 microns was plated. The composition was measured before and after pole tip trimming. The results in Fig. 3 shows that the composition difference between the yoke and pole tip changed from 0 to 0.5% Fe as the track width decreased from 14 to 5 microns. These results indicate that a large portion of the composition difference seen between yoke and pole tip in Fig. 2 is due to the artifact of the measurement technique, and the secondary X-ray fluorescence correction for track width less than 14 microns. Although, thin film thickness correction is performed for NiFe films measured with electron microprobe, no width correction is done. Therefore, narrow geometry will result in artificially lower Fe%.

It is clear from these results that the composition difference is insensitive to any width correction as long as the track width is more than 14 microns. In the case of flat structures (Fig. 2), there was no composition difference between yoke and pole tip for track widths greater than 14 microns. However, for the structures with a step height of 17 microns, there was clearly a 0.4% Fe difference for track width greater than 14 microns.

The composition difference between the yoke and pole tip for the track width of 5 microns was 0.9% (Fig. 2). If the 0.4% difference was due to the step height of 17 microns, the net composition difference due to the pole width will only be 0.5% Fe. However, from the study of the flat structure shown in Fig. 3, the artifact of the measurement correction technique itself can account for all of the difference. This showed that there is no substantial degradation in composition uniformity for plating of track width as narrow as 5 microns.

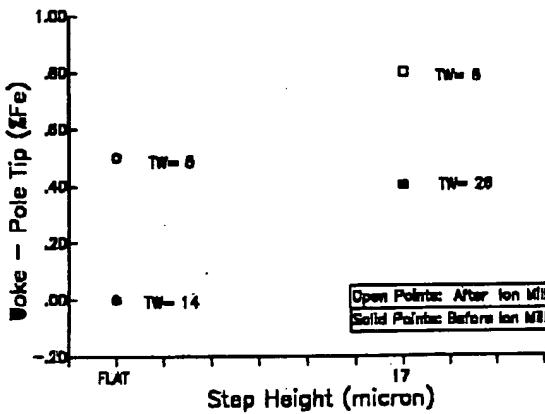


Fig. 3 Composition difference between the yoke and pole tip, before and after ion milling for different step heights. Track width (TW) are listed next to the points.

To examine the effect of step height, the track width was kept constant at 26 microns to minimize measurement error. Fig. 4 shows that as the topography changed from zero to 20 microns, the composition difference between the yoke and pole tip changed from zero to 0.5%. The least square curve fitting (dotted line in Fig. 4), shows a linear correlation between the step height and composition difference. These results clearly show that there is a composition difference between the pole tip and yoke at higher topographies with the yoke being more iron-rich. The two major mechanisms which can explain this composition difference are related to localized current density and mass transfer. Several authors have postulated that the composition nonuniformity is due to the current density differences at yoke and pole tip during plating [2,7]. Since the pole tip is defined by photoresist walls, current crowding near the edge of the walls during plating might result in higher effective current density in the pole tip area, especially when the pole width is narrow. To sort out the effect of mass transfer from that of localized current density, an experiment was designed to plate Permalloy on a topography of 17 microns without definition of pole tip or yoke. The results of this study showed that there was an obvious composition difference of 0.35% Fe between the top and bottom of the structures even in the absence of current crowding effect. This composition difference, can account for almost 90% of the difference seen in Fig. 2 for track width of 26 microns. In other words, mass transfer was the predominant factor. It is known that ferrous ions in the Permalloy plating bath are under mass transfer influence. Therefore, the effective diffusion layer thickness for ferrous ions is smaller at higher topography (such as the yoke) than that at the pole tip, resulting in more iron to be deposited in the yoke region of the head.

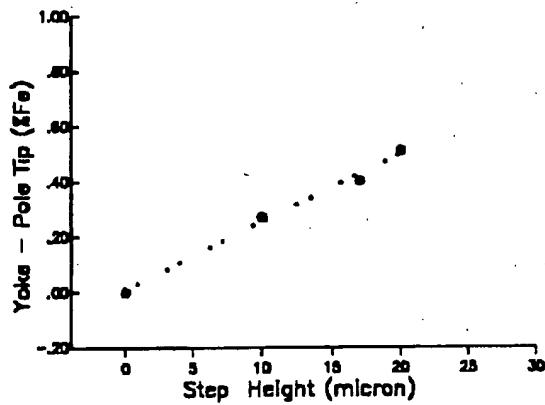


Fig. 4 The effect of step height on composition uniformity.

CONCLUSIONS

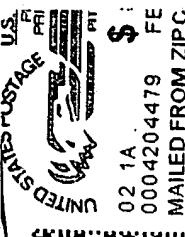
The effect of track width and topography on composition uniformity of the electroplated Permalloy in thin-film heads have been studied. A linear correlation was found between composition difference of the yoke to pole tip and topography. In all cases, it was observed that % Fe in the Permalloy was higher in the area with topography than that in the flat area. This was explained by the diffusion mechanism as opposed to a current crowding model. The results also suggested that electroplating could be employed to deposit Permalloy in track width as narrow as 5 microns without substantial degradation in composition uniformity.

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